

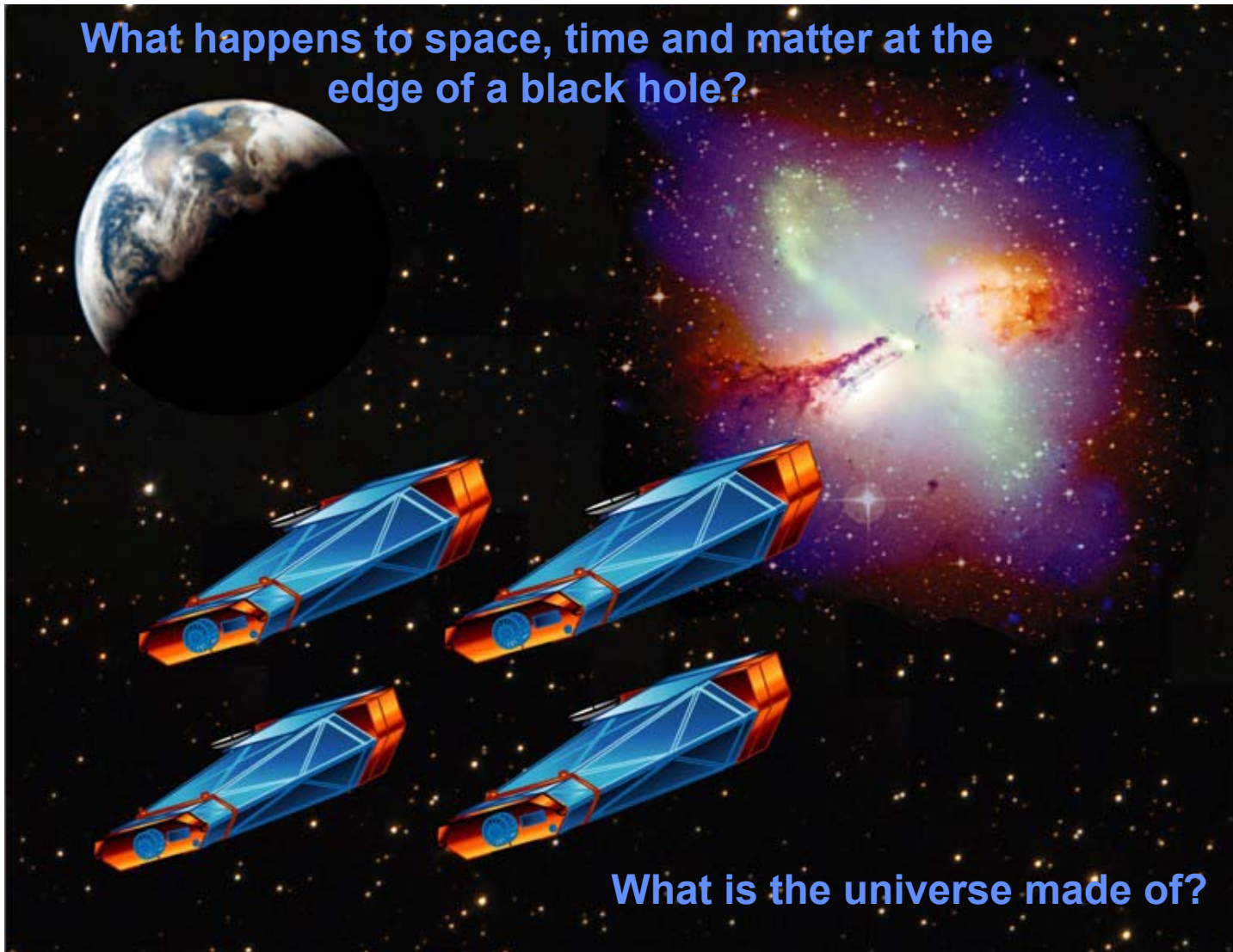


# Constellation-X

## Project Scientist Update



What happens to space, time and matter at the edge of a black hole?



What is the universe made of?

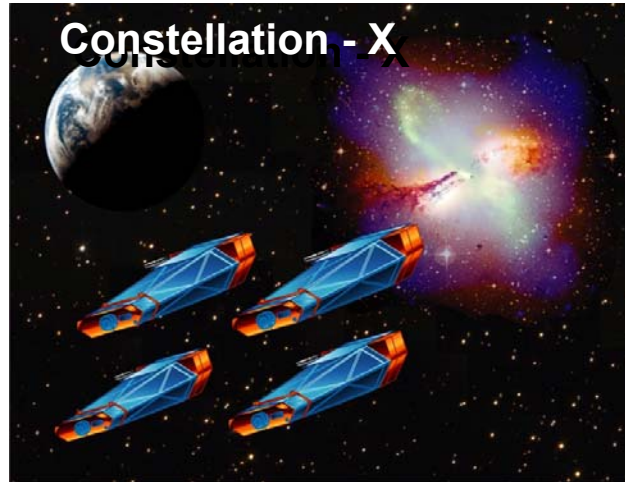
<http://constellation.gsfc.nasa.gov>



# Highlights since last meeting (Nov 2001)



- **Grating and CCD spectra from Chandra and XMM-Newton**
  - Demonstrating the richness and power of X-ray spectroscopy
  - Feedback into Constellation-X mission requirements (see Jay Bookbinder Talk)
- **NAS Turner committee on the physics of the universe**
  - Gives Constellation-X high priority
- **NASA Strategic Planning**
  - Reaffirmed Constellation-X as near term priority
- **Constellation X-ray Mission Spectroscopy Workshops**
  - First in May 2002 at Columbia University
- **Major progress with technology**
  - Substantial technology funding allowing flight scale prototype of optics
  - Continued progress with detector technologies
- **Technology Readiness and Implementation Plan (TRIP) review**
  - Access plans to mature technology of Constellation-X and LISA
  - Review implementation plans
  - See Paul Hertz Talk



An X-ray VLT



## Use X-ray spectroscopy to observe

- Black holes: strong gravity & evolution
- Dark Matter throughout the Universe
- Production and recycling of the elements

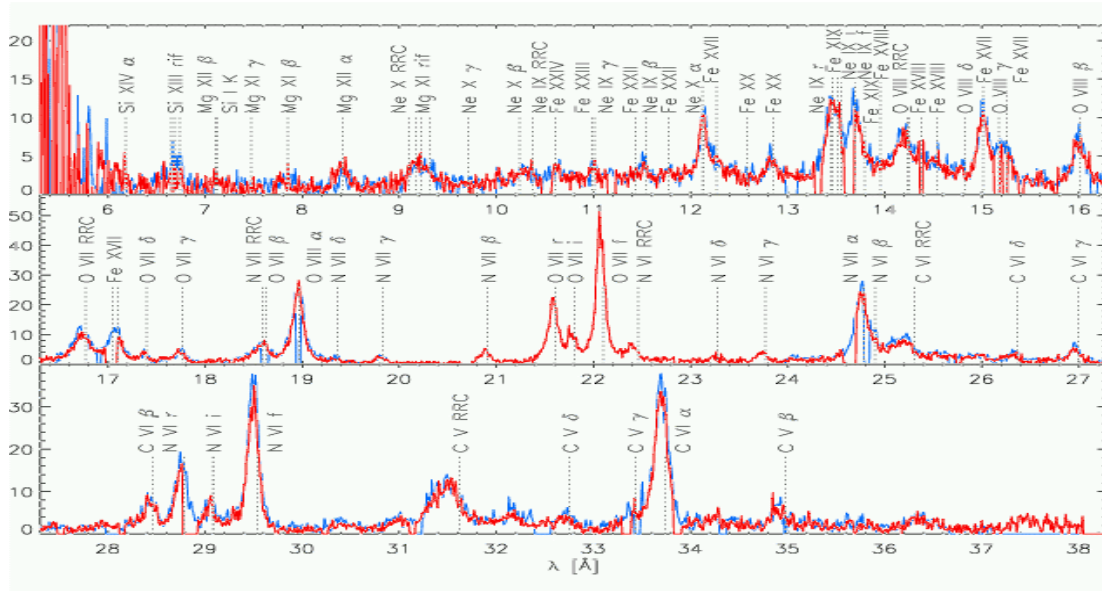
## Mission parameters

- Telescope area: 3 m<sup>2</sup> at 1 keV  
*25-100 times XMM/Chandra for high resolution spectroscopy*
- Spectral resolving power: 300-3,000  
*3-5 times better than Astro-E2 at 6 keV*
- Band pass: 0.25 to 40 keV  
*100 times RXTE sensitivity at 40 keV*

Enable high resolution spectroscopy of faint X-ray source populations

## Constellation-X Grating Optimization

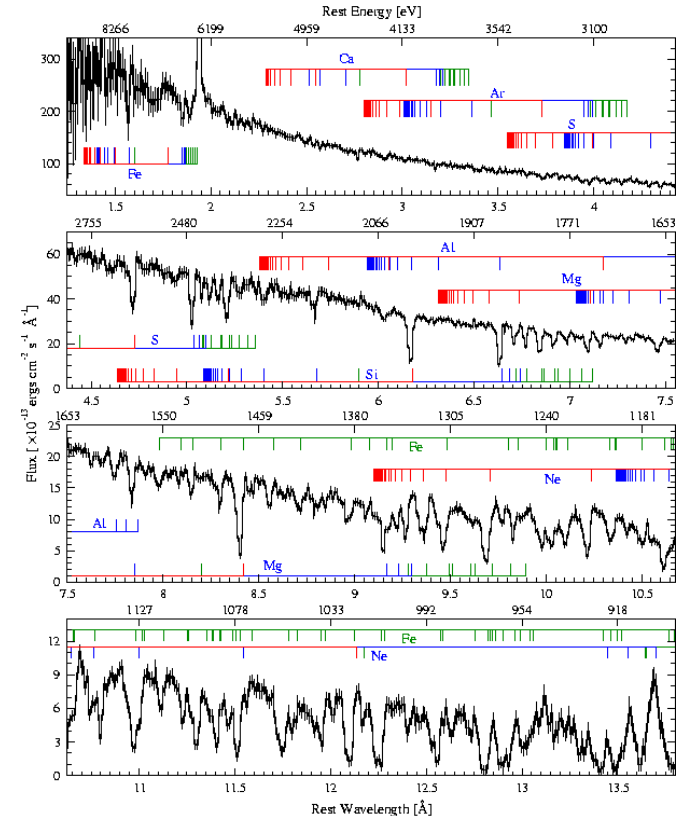
New grating results from Chandra and XMM-Newton are providing important information to guide the optimization of the gratings on Constellation-X



## XMM RGS Spectrum of NGC1068 Kinkhabwala et al 2002

The final Constellation-X spectral resolution & collecting area vs. wavelength can be tuned and will depend on the final grating parameters

- *depends on progress in technology program*
- *and selection of in plane vs. off plane designs*



## Chandra HETGS Spectrum of NGC3783 from Kaspi et al (2002)



# X-ray Spectroscopy Comes of Age



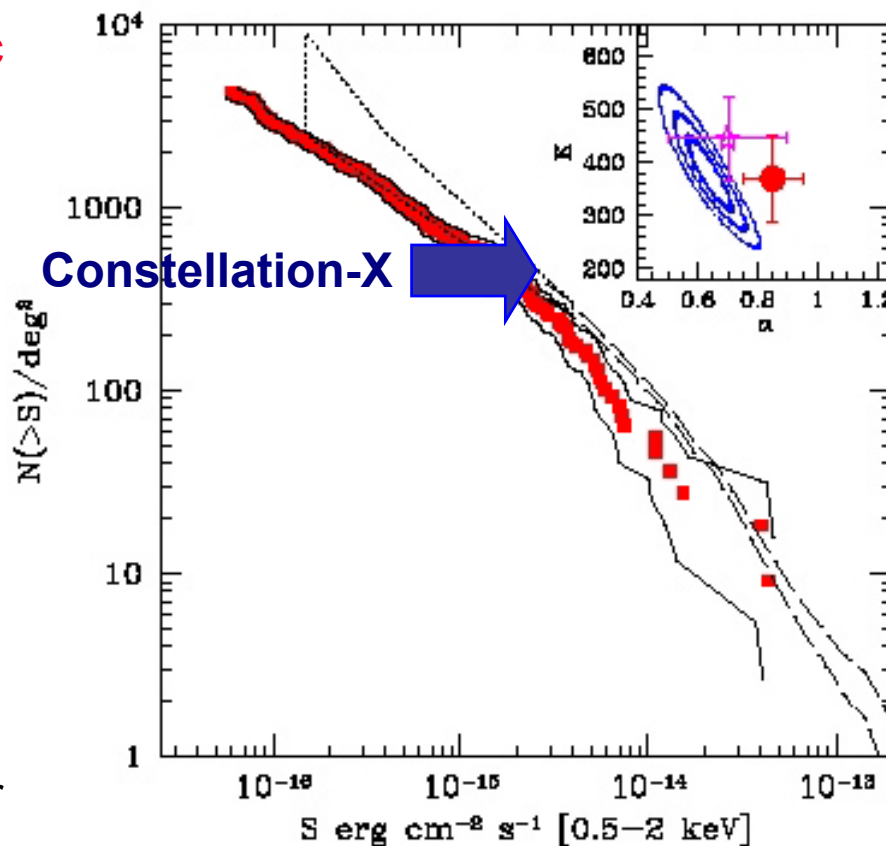
The current threshold for finding X-ray selected AGN exceeds the spectroscopic capability of optical telescopes to identify the host galaxy (33% objects at  $I > 24$ )

High resolution ( $R > 300$ ) spectrometers on Chandra, XMM-Newton and Astro-E2 typically reach fluxes where the sky density is 0.1 to 1 sources per sq degree

**X-ray imaging has outstripped both optical and X-ray spectroscopy!**

Constellation-X will increase by a factor 1000 the number of sources available for high resolution spectroscopy

Chandra Log N - Log S

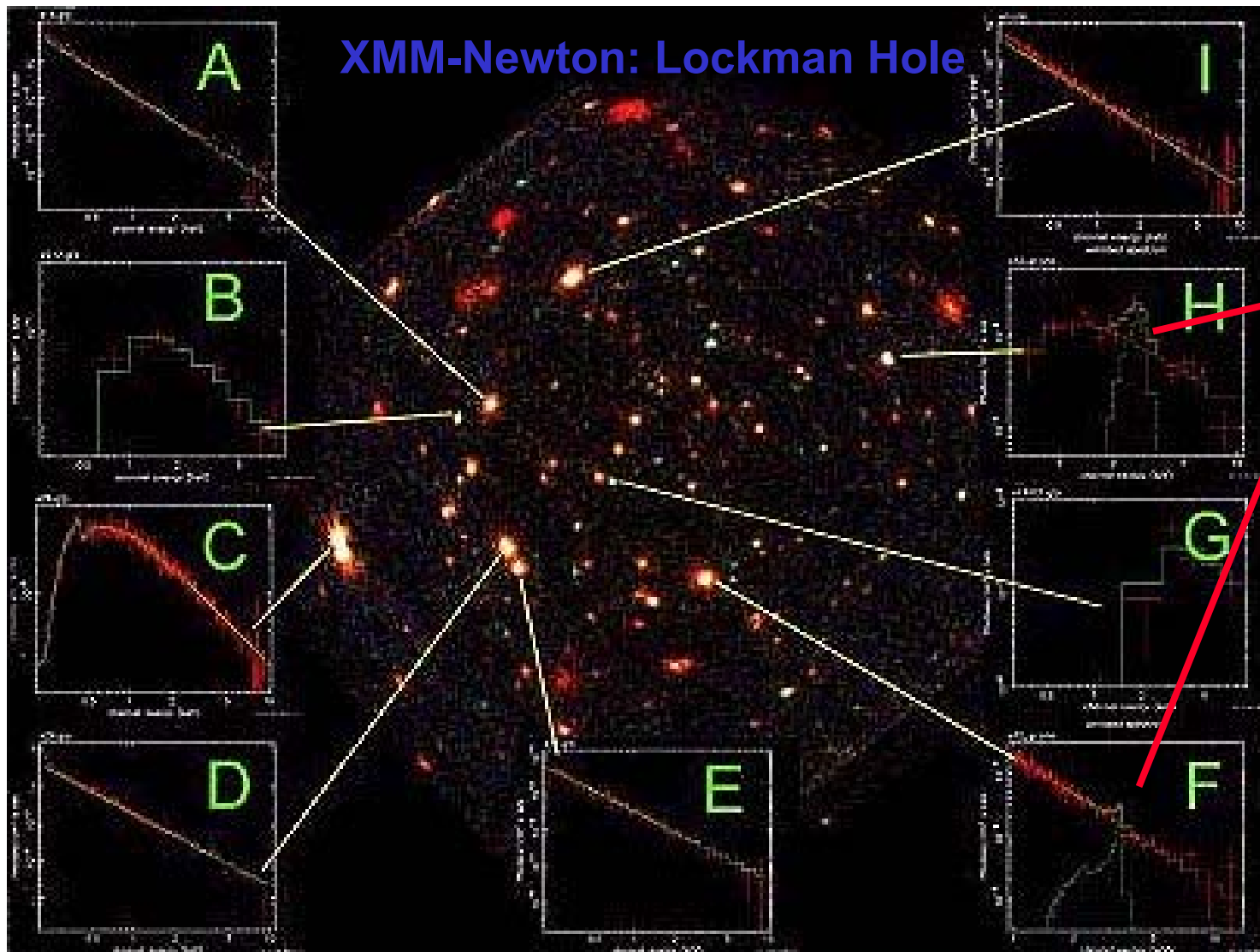


**Current capabilities**

**Constellation-X will obtain high resolution spectra of the faint X-ray sources to determine redshift and source conditions**

# XMM Spectra of the Sources of the X-ray Background

## XMM-Newton: Lockman Hole



Strong Fe K line emission allows redshift and nature of object to be determined.

Wide variety of x-ray spectra.

Strongly absorbed sources - (B,C,G) have red optical colors and show weak signs of optical activity.

**Constellation-X will provide high resolution spectra of these sources**

# **Quarks to the Cosmos Study**

## **Committee on the Physics of the Universe (CPU)**

- **November 1999:** Dan Goldin asks the National Academy to carry out a study on science at the intersection of physics and astronomy
- **Charge:**
  - Phase 1)** Identify science opportunities at the INTERSECTION (not union) of physics and astronomy
  - Phase 2)** Recommend a strategy for achieving these opportunities
- **January 2001:** Phase 1 Report: The 11 Questions
- **April 2002:** Final Report: 11 Questions and 7 Recommendations

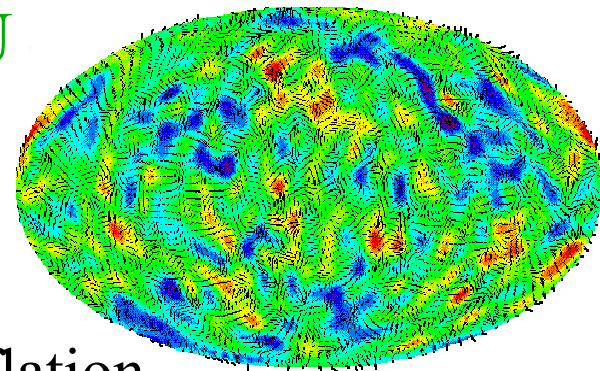
Funded jointly by DOE, NASA, NSF  
to complement the Astronomy and Physics Decadal Surveys  
<http://www.nas.edu/bpa/projects/cpu>

# The Seven Recommendations of the CPU

## THREE NEW INITIATIVES

### Cosmic Microwave Polarization Experiment

measure the gravity-wave signature of inflation  
and determine when inflation took place



NASA, NSF & DOE

SNAP



### Wide-Field Telescope in Space

use supernovae to probe the expansion  
history to get at the nature of dark energy

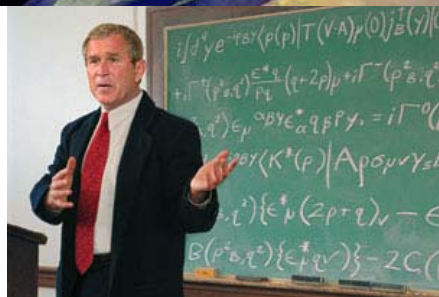
NASA & DOE

### Deep (> 4000 mwe) Underground Laboratory

determine neutrino masses and mixings

measure the lifetime of the proton

detect dark matter in our halo

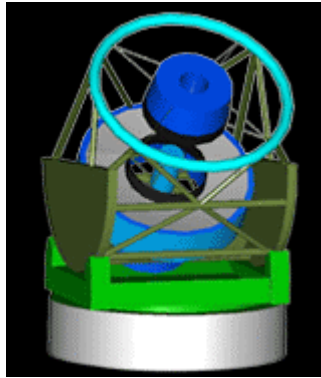


I expect you to measure w

September 18/19, 2002

NSF & DOE

# Support of 3 Projects Identified by Astronomy Decadal Survey On Their Basis of Their Ability to Address Our 11 Questions



## LSST (Large Synoptic Survey Telescope)

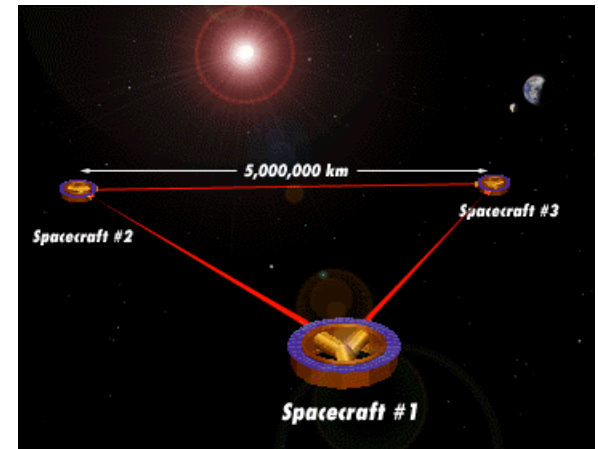
probe dark energy by weak gravitational lensing

NSF

## LISA (Laser Interferometer Space Antenna)

test GR by detecting gravity waves  
from colliding massive black holes

NASA & ESA

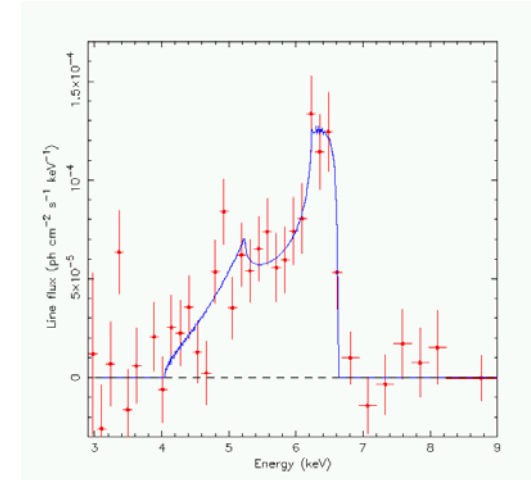
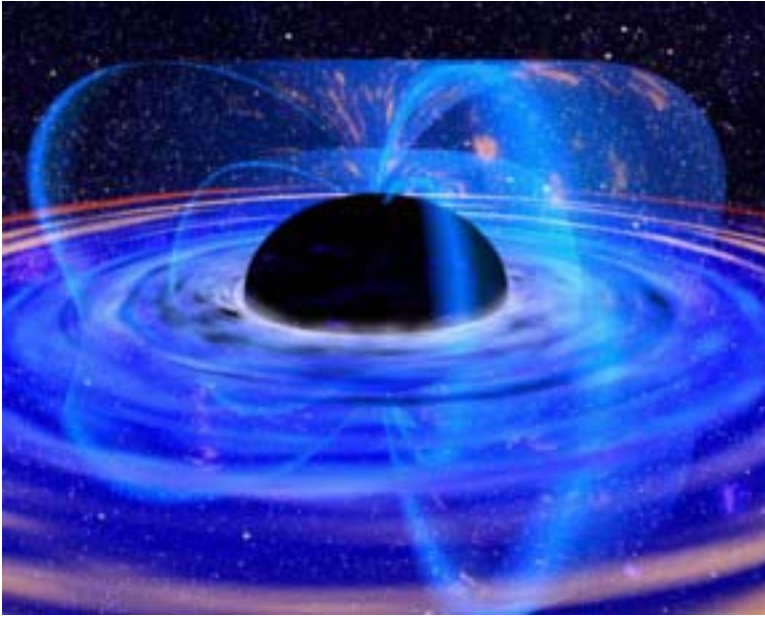


## Con-X (Constellation X)

probe the event horizon of black holes  
by Iron-line reverberation

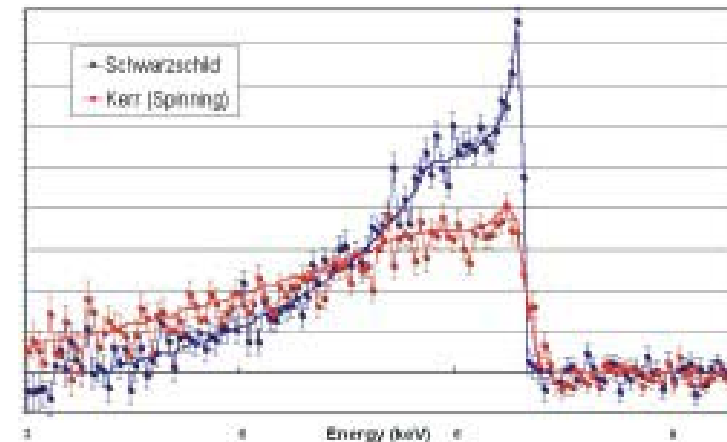
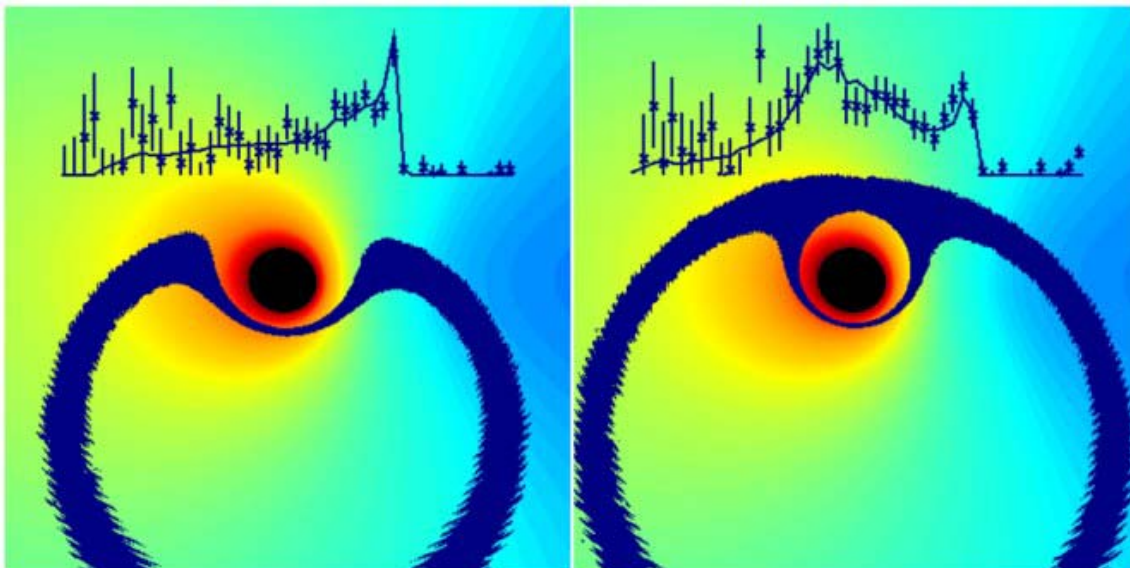
NASA

# Iron-line Reverberation Mapping of Black Holes



**ASCA evidence for  
MCG 6-30-15**

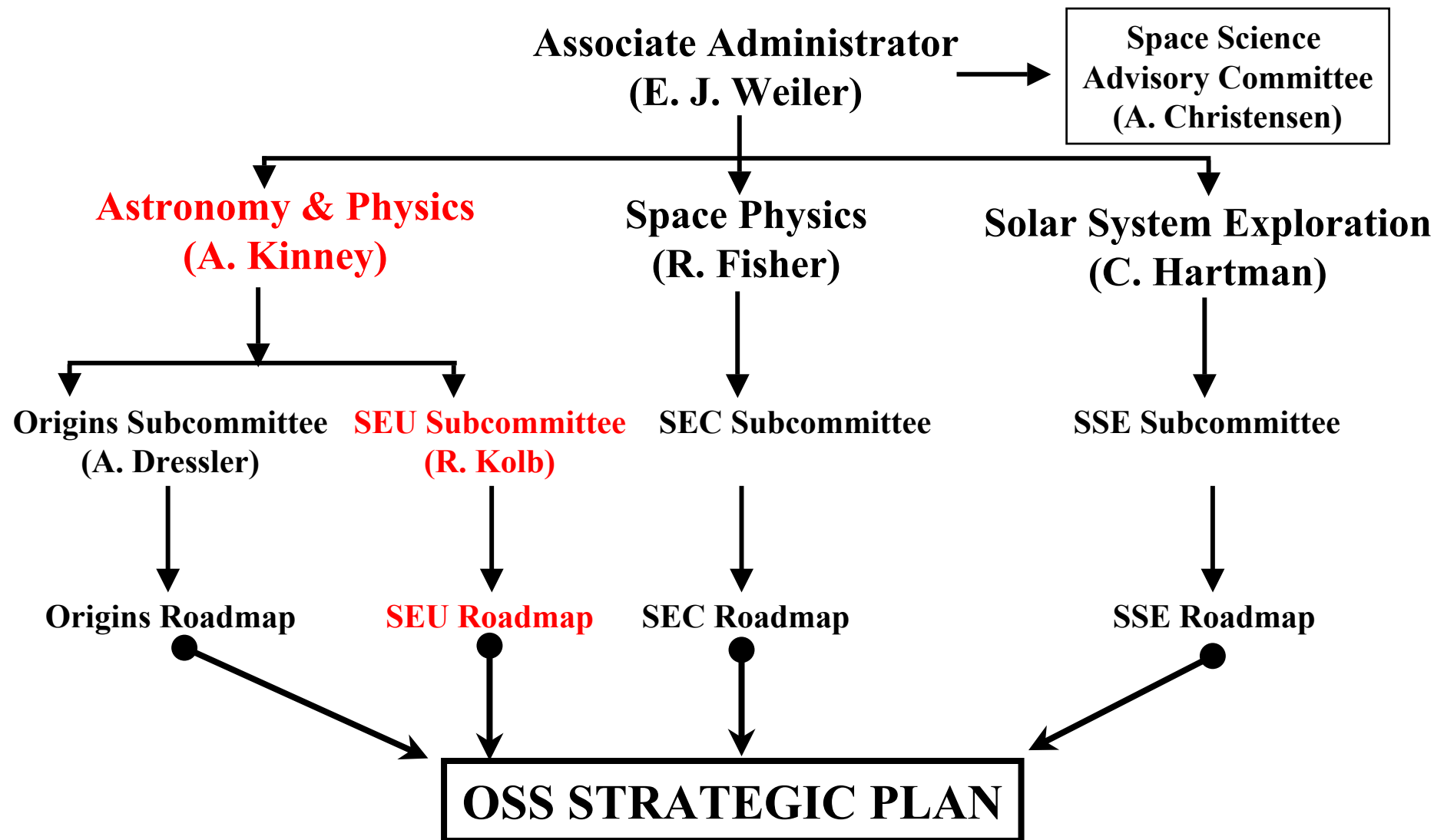
## Simulated Performance of Con-X



# Roadmap & Strategic Plan

- OSS is creating a new Strategic Plan for 2003-2028.
  - Space Science Advisory Committee approves plan.
- Each science theme is creating a Roadmap as input to the Strategic Plan.
  - Each Subcommittee of SScAC sets Roadmap.
    - SEUS chaired by Rocky Kolb (Fermilab).
  - SEU Roadmap created by a Roadmap Team reporting to SEUS.
    - Roadmap Team chaired by Sterl Phinney (Caltech).

# Office of Space Science Advisory Structure



# SEUS

Rocky Kolb, Chair (Fermilab)

Joel Bregman (Michigan)

Lynn Cominsky (Sonoma State)

Chuch Dermer (NRL)

Kathy Flanagan (MIT)

Tim Heckman (JHU)

Jackie Hewitt (MIT)

Dan Lester (Texas)

Brad Peterson (Ohio State)

Sterl Phinney (Caltech)

Simon Swordy (Chicago)

Nick White (GSFC)

Ned Wright (UCLA)

Hal Yorke (JPL)

Paul Hertz, Exec Sec (NASA)

# Roadmap Team

Sterl Phinney, Chair (Caltech)

Sean Carroll (Chicago)

Sarah Church (Stanford)

Kathy Flanagan (MIT)

Roy Gould (CfA)

Craig Hogan (Washington)

Steve Kahn (Columbia)

Dan Lester (Texas)

Bob March (Wisconsin)

Mike Shull (Colorado)

Simon Swordy (Chicago)

Nick White (GSFC)

Rocky Kolb, SEUS Chair (Fermilab)

Paul Hertz, Exec Sec (NASA)

# SEU ROADMAP SCHEDULE

November 1	Begin biweekly telecons
December 2	Science input (by invitation)
December 3-4	Mission input (by invitation) to SEUS
January 6	Science input (by invitation)
January 6	Input from McKee-Taylor Committee Report
January 31	White papers due
February 26	Input from Turner Committee Report
February 26-27	White papers input / Prioritization meeting
April 8	Prioritization meeting
April 9-10	Present Roadmap outline to SEUS
February-July	Technology Sub-team
February-July	E/PO Sub-team
April-July	R&A Sub-team
April-July	Roadmap Writing
August 12-13	Present draft text to SEUS
September 1	Roadmap complete
November 6-8	Strategic Plan Workshop

<http://universe.gsfc.nasa.gov/roadmap.html>

# SEU Roadmap Outline

- Beyond Einstein
  - What powered the Big Bang?
  - What happens to space, time, and matter at the edge of a Black Hole?
  - What is the mysterious Dark Energy pulling the universe apart?
- Cycles of Matter and Energy
  - Understand the development of structure in the universe
  - Explore the cycles of matter and energy in the evolving universe

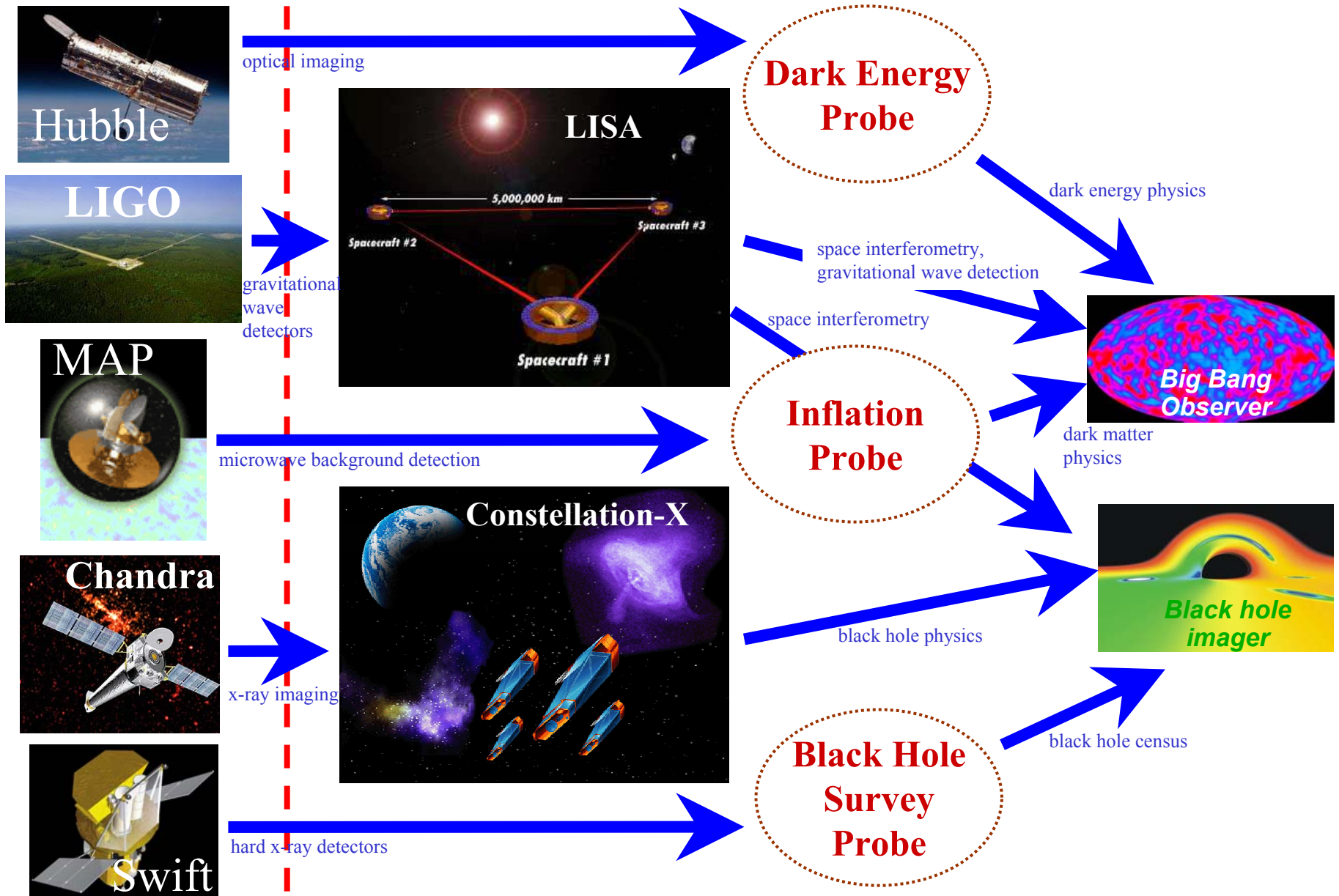
# Beyond Einstein Program Strategy

- **Establish long term science goals to drive a linked science and technology program to enable the vision missions:**
  - Black Hole Imager
  - Big Bang Observatory
- **Great Observatory Missions that examine black holes in detail and provide critical technology steps towards the vision missions**
  - Constellation-X: Event horizon of black holes
  - LISA: Gravitational waves from merging black holes
- **Fully competed Einstein Probe Missions that address key science objectives with moderate sized missions**
  - Dark Energy Probe
  - Big Bang Probe
  - Black Hole Probe

## **Key features are:**

- *Part of a tri-agency (NASA/NSF/DOE) coordinated program on the fundamental physics of the universe.*
- *Fully competed acquisition strategy*
- *Strong linkage to education program and technology*
- *All missions endorsed by the National Academy of Sciences as high priorities*

# The Beyond Einstein Program



# Program Components

- **“Einstein Great Observatories”: Strategic Missions (2010-2015)**
  - Constellation-X: A spectroscopic observatory that uses X-ray emitting atoms as clocks to follow the fate of matter falling into black holes.
  - LISA: The first space-based gravitational wave observatory uses gravitational waves to measure the dynamic structure of space and time around black holes.
  - Launches in FY11 and FY14.
- **“Einstein Probes”: Fully competed, peer-reviewed missions (\$300M-\$450M) launched every 3-5 years starting in 2010 to**
  - Determine the nature of the Dark Energy that dominates the universe.
  - Search in the microwave background for the signature of the beginning of the Big Bang
  - Take a census of Black Holes of all sizes in the universe.
  - First launch in FY12.
- **A Technology Program to enable ultimate Vision Missions (after 2015) to:**
  - Directly detect gravitational waves echoing from the beginning of the Big Bang
  - Image matter near the event horizon of a Black Hole
- **An Education and Public Outreach Program to:**
  - Inspire the next generation of scientists.
  - Support national science standards and benchmarks.

# 1st Constellation X-ray Mission Spectroscopy Workshop

- **Objectives:**
  - Discuss and educate the community about the power of X-ray spectroscopy
  - Application of X-ray line plasma diagnostics to astrophysical setting
  - Continue to develop Design Reference Mission (observing plan) for Constellation-X
  - Highlight science potential of Constellation-X
- **First workshop in May 2002 hosted by Columbia University:**
  - Highlight results from gratings and CCDs on Chandra and XMM
  - Discuss potential for Astro-E2
  - Steve Kahn and Frits Paerels
- **Repeat every 1-2 years?**